Very High Power* THz Radiation from Relativistic Electrons

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* = Megawatt peak, 20 watt average

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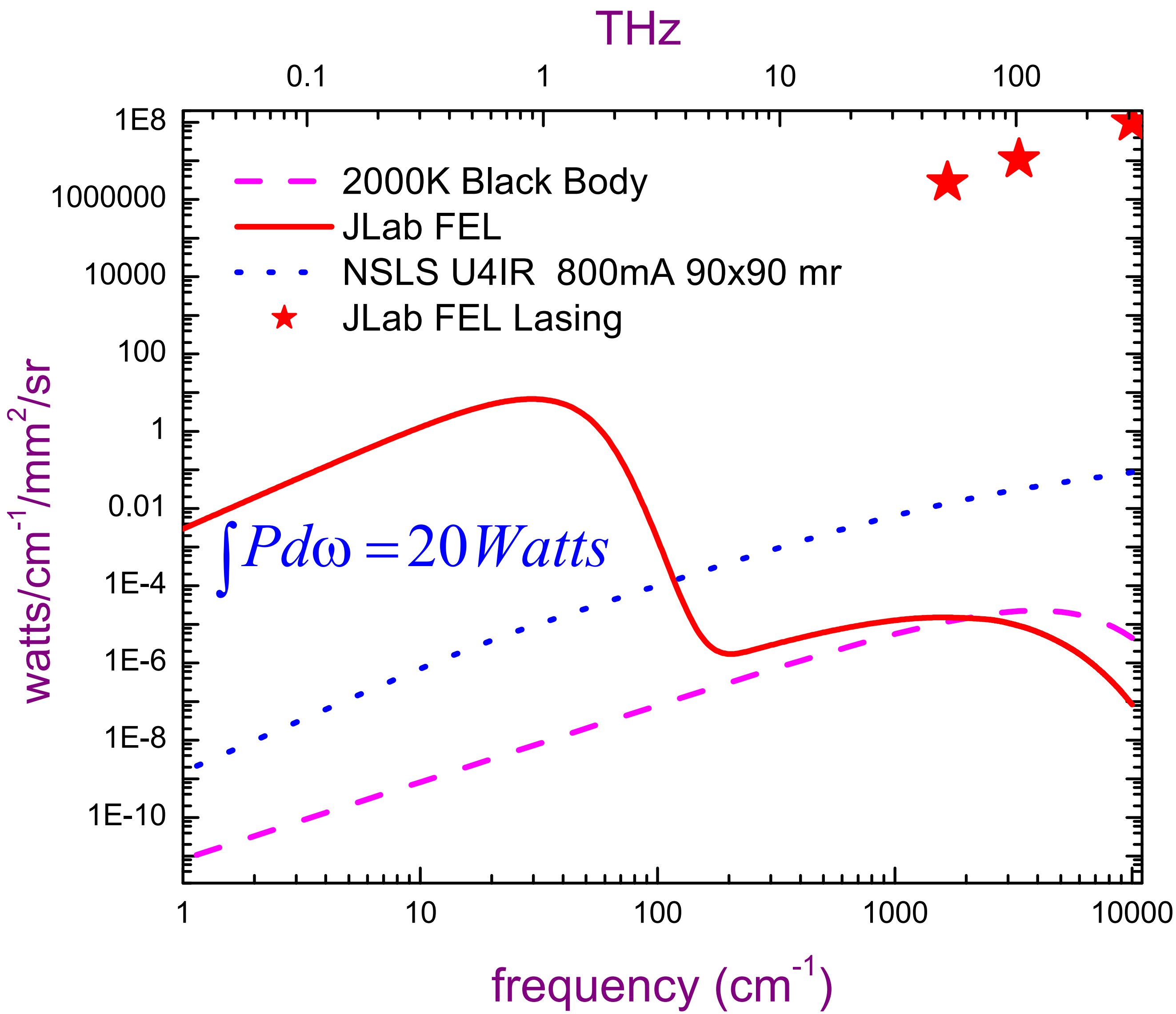
Brookhaven National Laboratory



THz
0.1
1
10
100
1E8
1000000
10000
100
1
0.01
1E-4
1E-6
1E-8
1E-10
2000K Black Body
JLab FEL
NSLS U4IR 800mA 90x90 mr
JLab FEL Lasing
$\int P d\omega = 20 Watts$
watts/cm^{-1}/mm^2/sr
1
10
100
1000
10000
frequency (cm^{-1})

Jefferson Lab Light Source Facility

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Jefferson Lab Free-electron Laser Facility

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Sustained Kilowatt Lasing in a Free-Electron Laser with Same-Cell Energy Recovery

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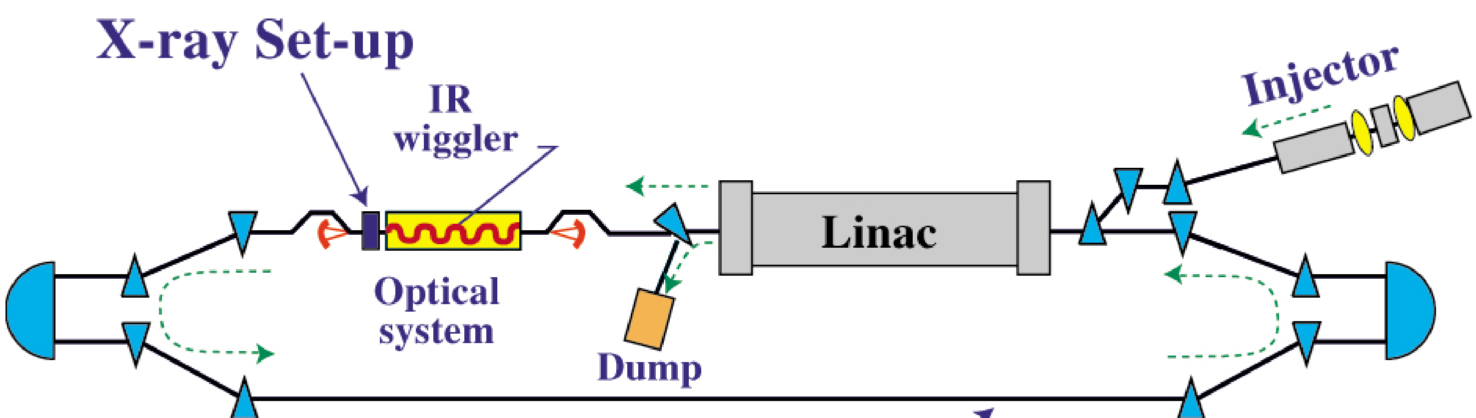
"Energy Storage Ring"



e⁻ recirculation beam line

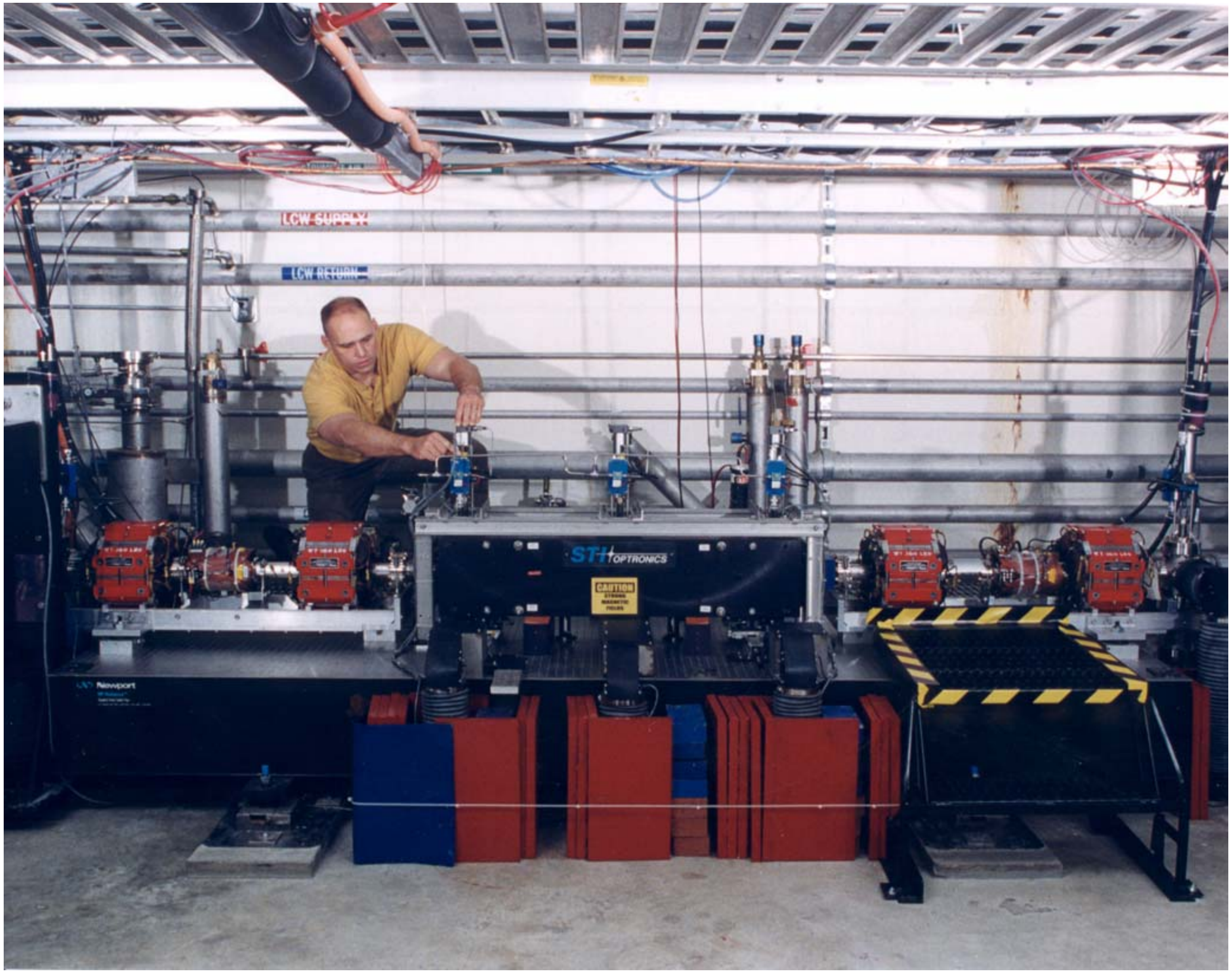
10 m

e-beam Specifications

- sub-picosecond pulse length
- up to 75 MHz rep rate
- 40 MeV electron energy

Jefferson Lab FEL Superconducting Linac

Jefferson Lab FEL Wiggler



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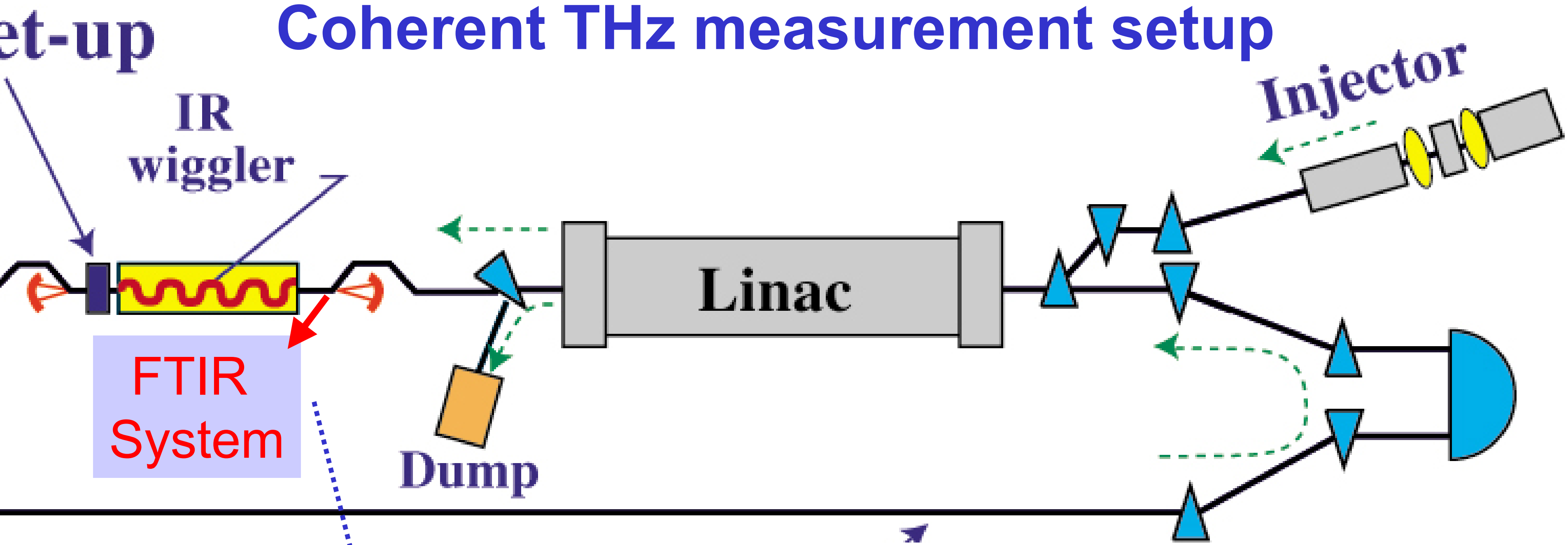
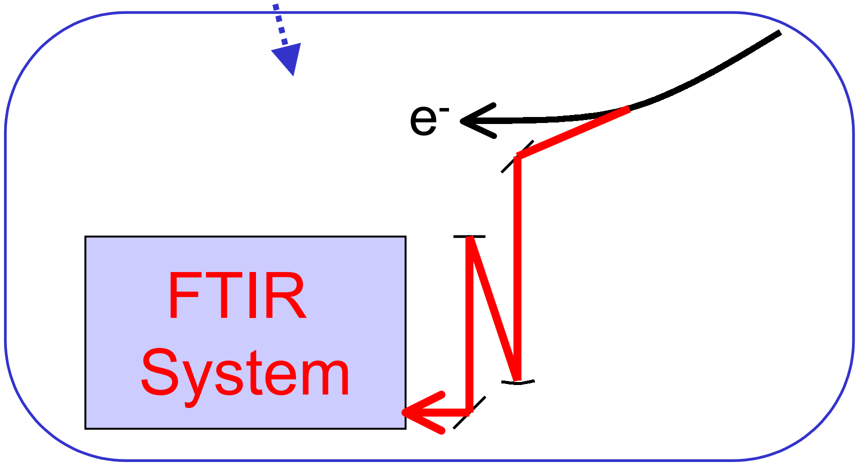
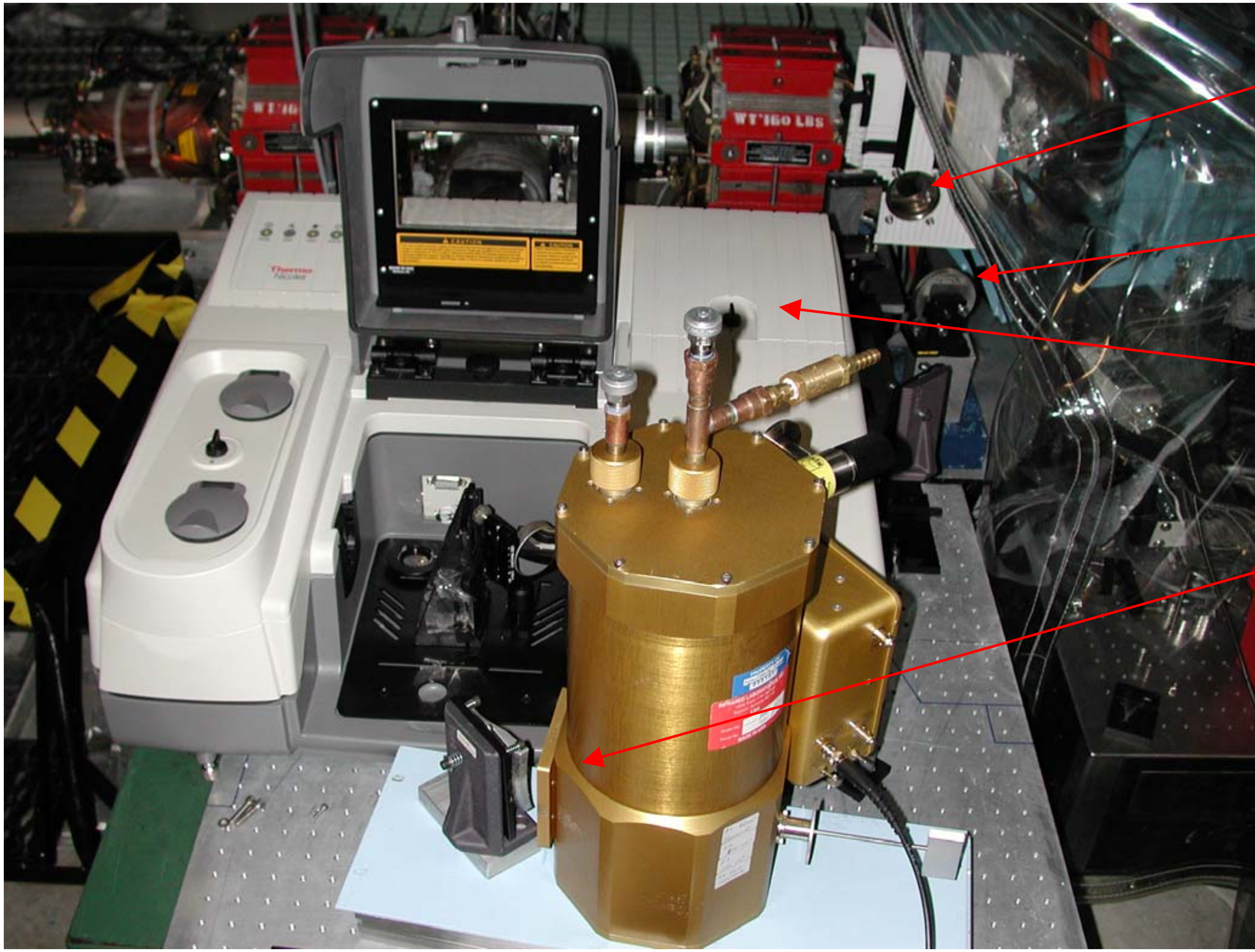
Coherent THz measurement setup





We measured the bend-magnet synchrotron radiation right before the FEL, when the beam is maximally compressed.

Coherent THz measurement setup



Crystal quartz window

Collimating optic

Nicolet Nexus 670 FTIR bench

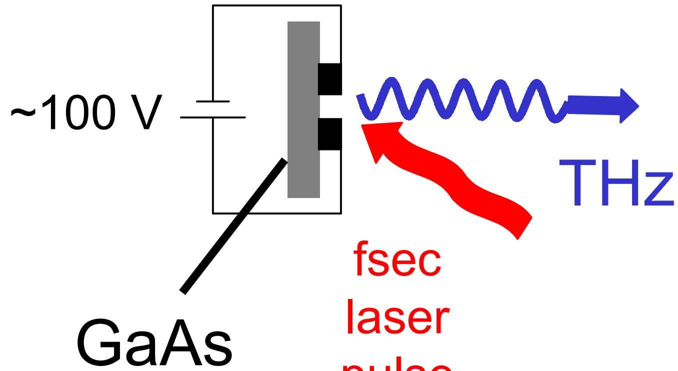
LHe cooled Si bolometer detector

Comparing Coherent THz Synchrotron and Conventional THz Sources

a=acceleration
c=vel. of light
γ=mass/rest mass

$$\text{Larmor's Formula: Power} = \frac{3e^2a^2}{2c^3}\gamma^4 \text{ (cgs units)}$$

Auston switch

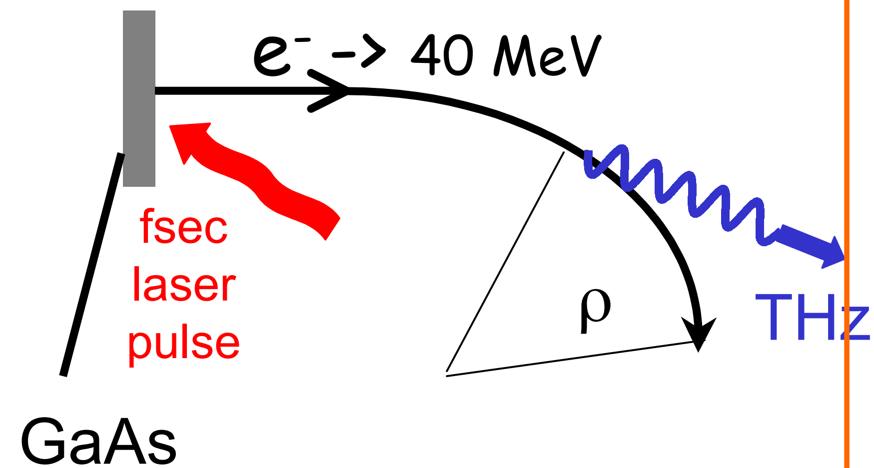


$$E = \frac{100V}{10^{-4}m} = 10^6 \, V/m$$

$$a = \frac{F}{m} = \frac{10^6 V \cdot e/m}{.5MeV/c^2} = \frac{10^6(3\times 10^8)^2}{0.5\times 10^6}$$

$$\cong 10^{17} \, m/sec^2$$

Synchrotron radiation



$$a = \frac{c^2}{\rho} = \frac{(3\times 10^8)^2}{1} \cong 10^{17} \, m/sec^2$$

$$if \; \rho = 1 \; m$$

Comparing Coherent THz Synchrotron and Conventional THz Sources

$$\text{Larmor's Formula: Power} = \frac{3e^2a^2}{2c^3}\gamma^4 \text{ (cgs units)}$$

$$\boxed{\text{Power} \propto \gamma^4}$$

Synchrotron

THz Antenna

$$\gamma = 1$$

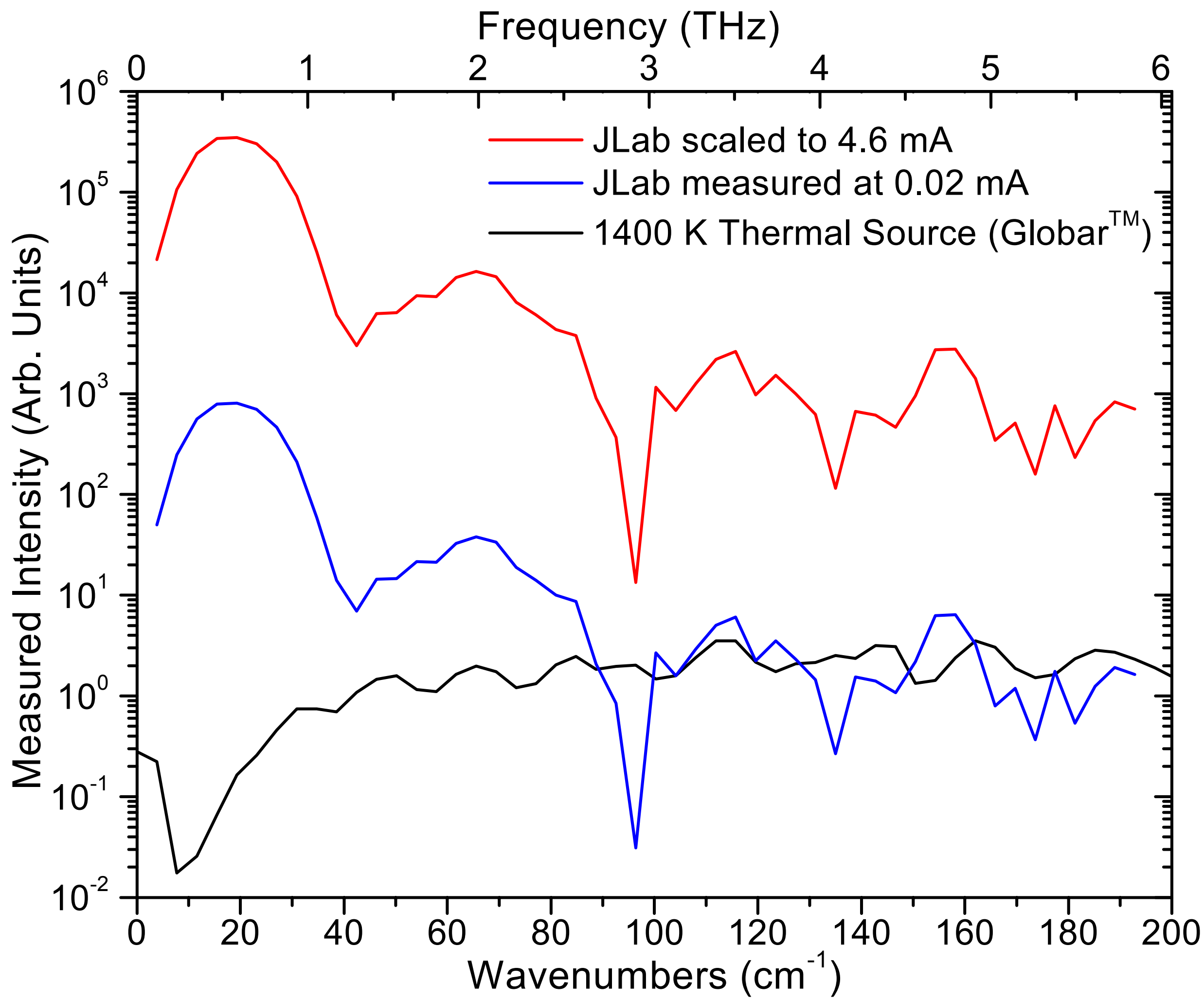
To compare radiation in the THz region, ~40 MeV electrons will get the critical energy into the IR. So,

$$\gamma \approx 75$$

$$\gamma^4 \approx 10^7!$$

Relativistic electrons gain a huge factor in THz power.

Coherent THz compared to thermal source



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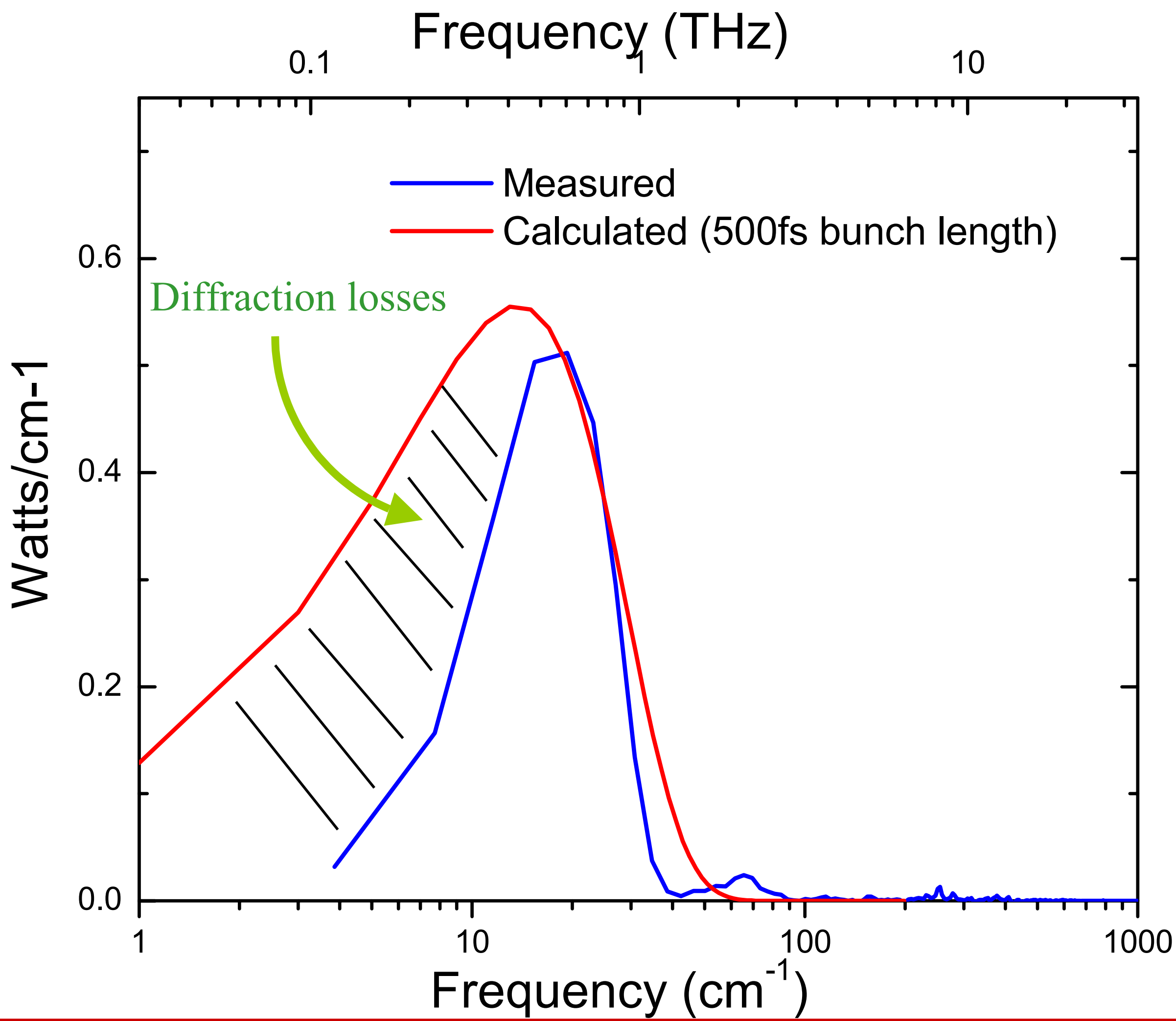
Coherent THz measurement



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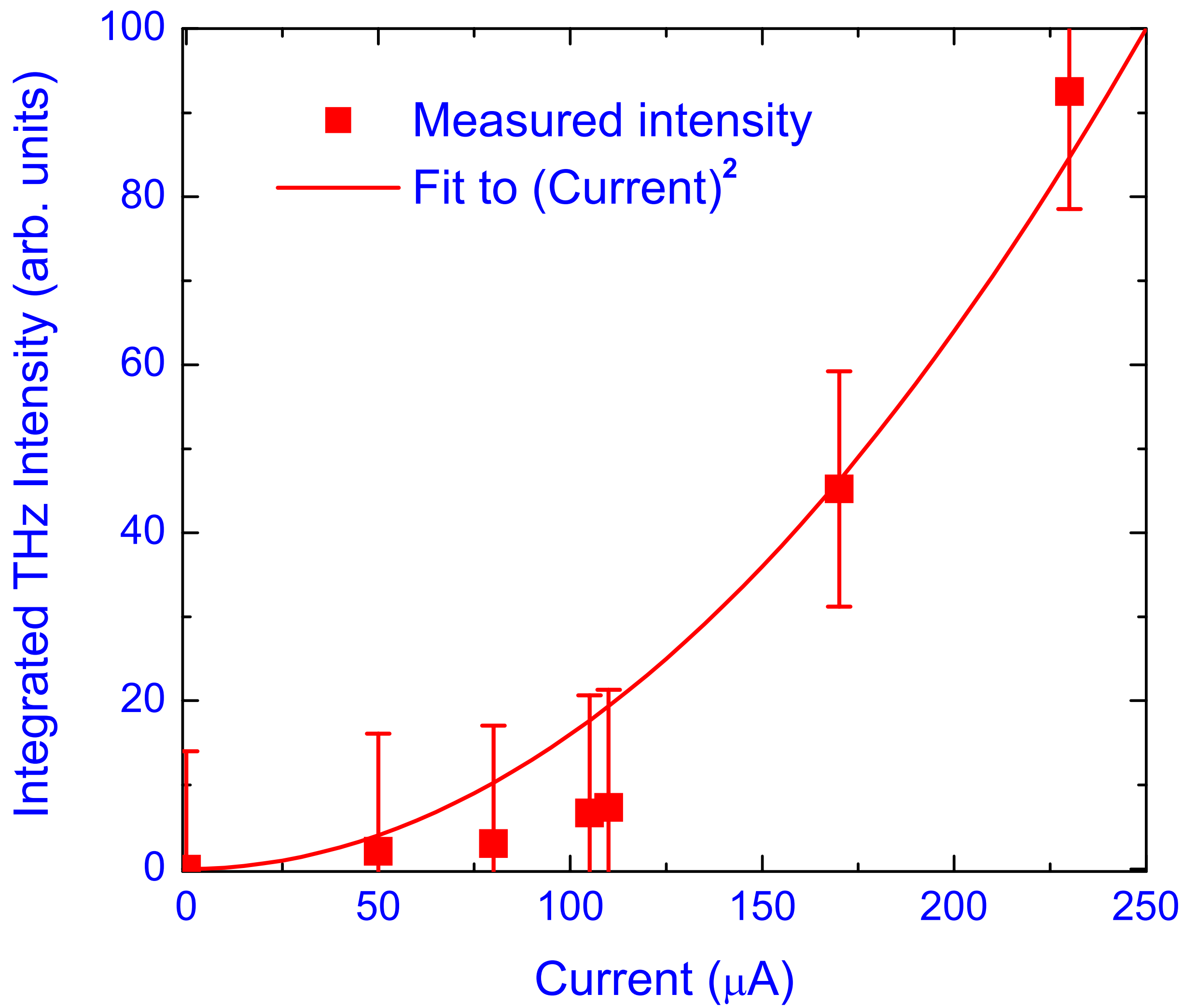
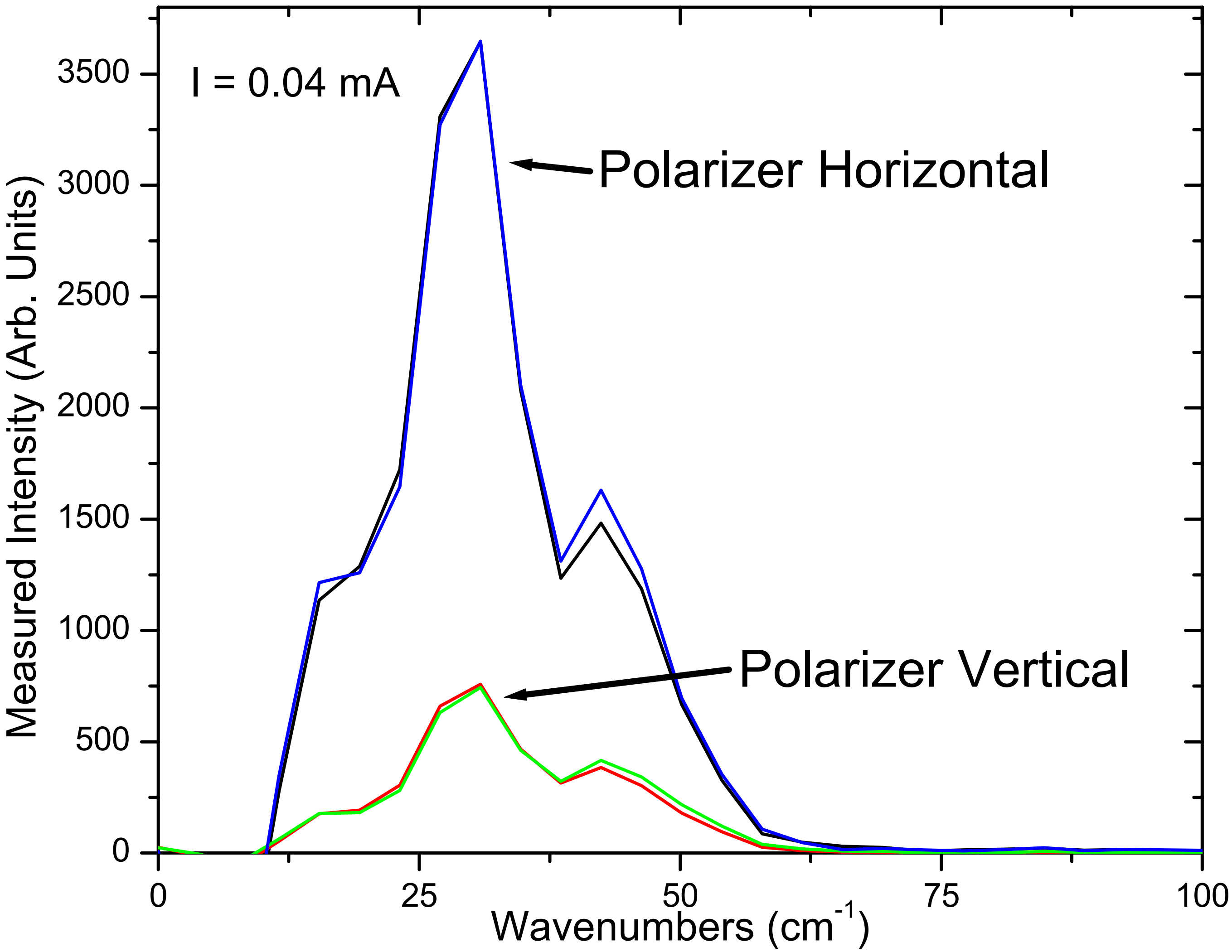
Jordan, Neil, Williams
Nature, to be published

Quadratic Dependence of THz Emission on Current



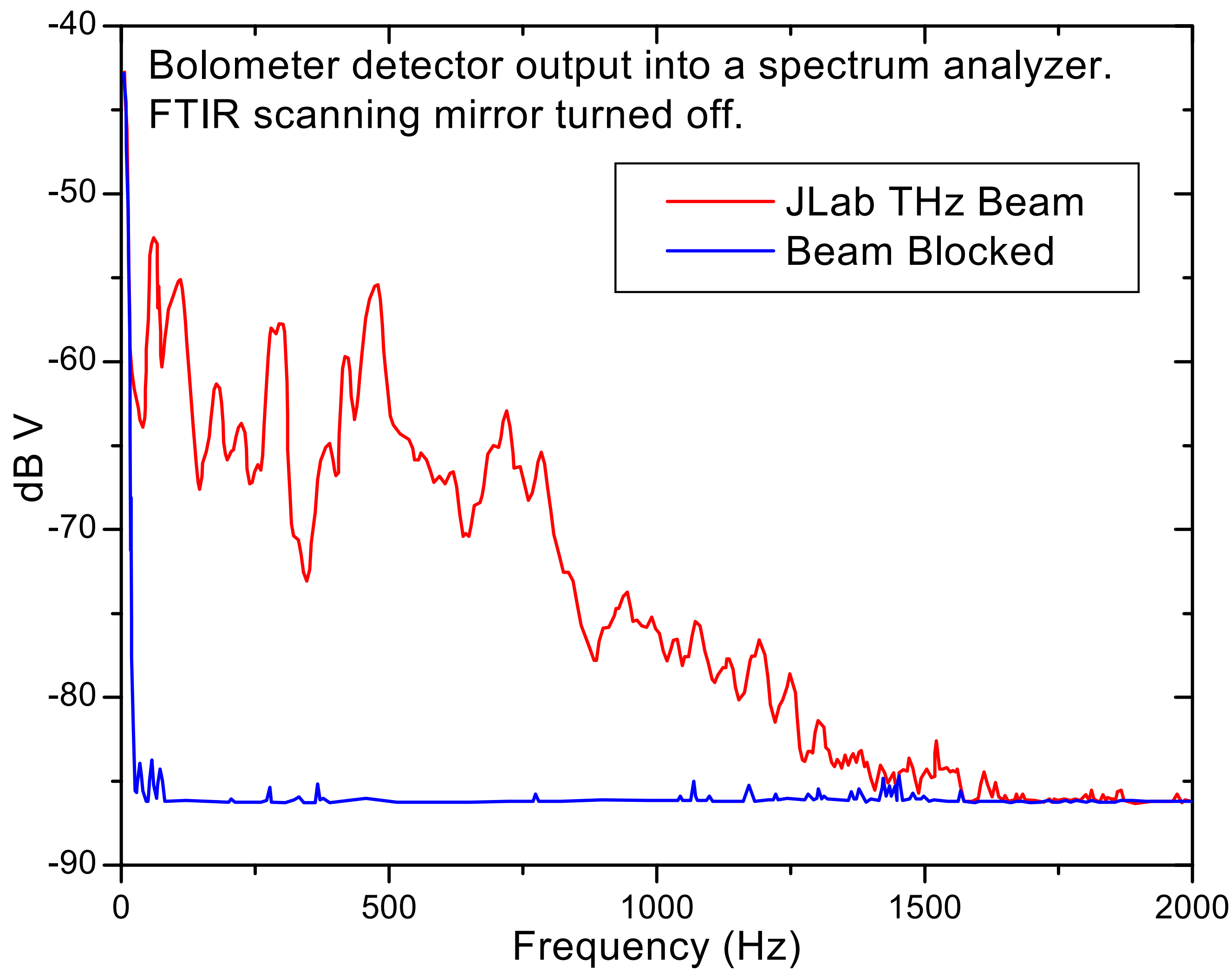
Polarization of Coherent THz



Expected polarization ratio for 60 mrad port at 30 cm^{-1} is 6:1.

We observed 5:1. Good agreement.

“Noise” vs. frequency



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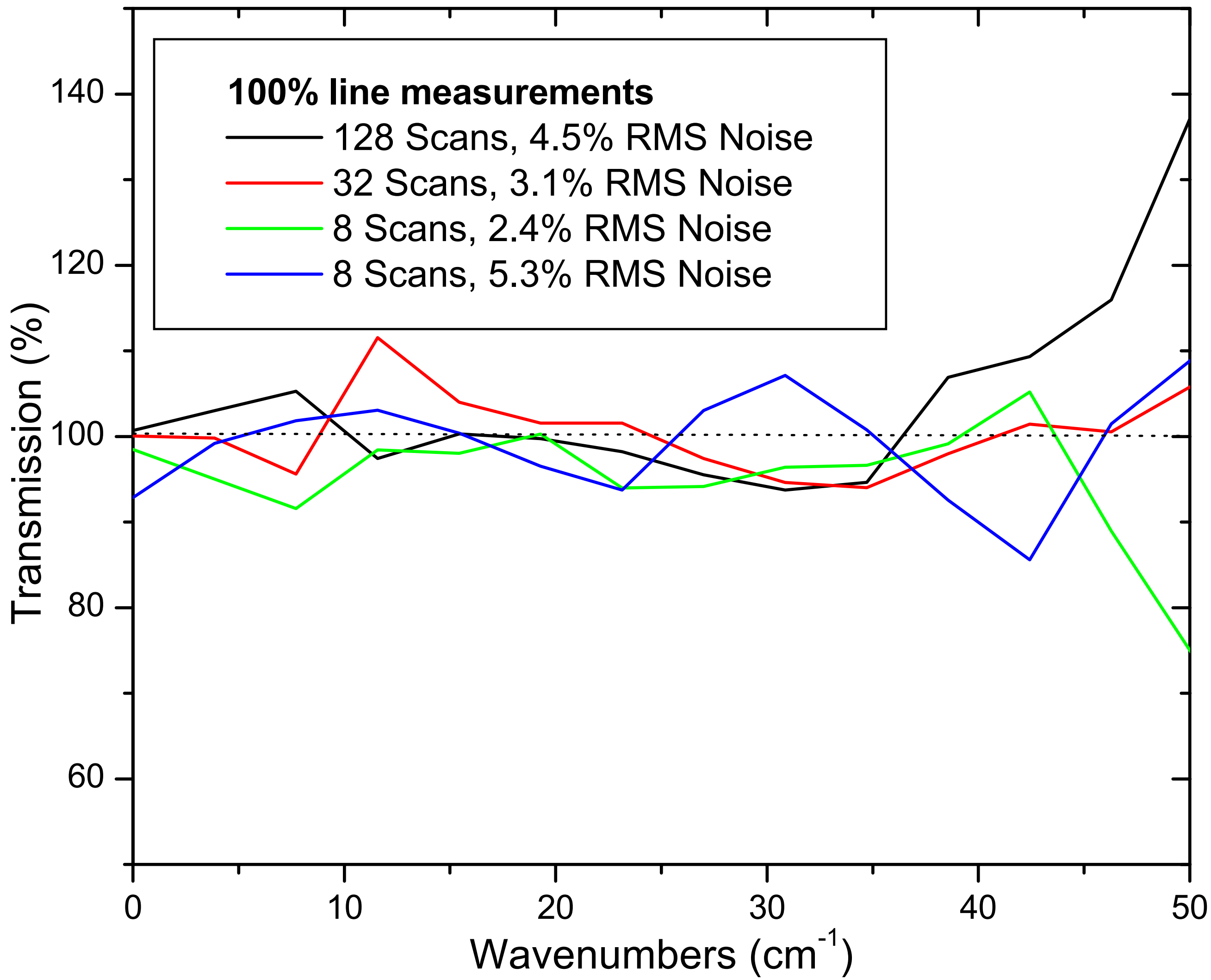
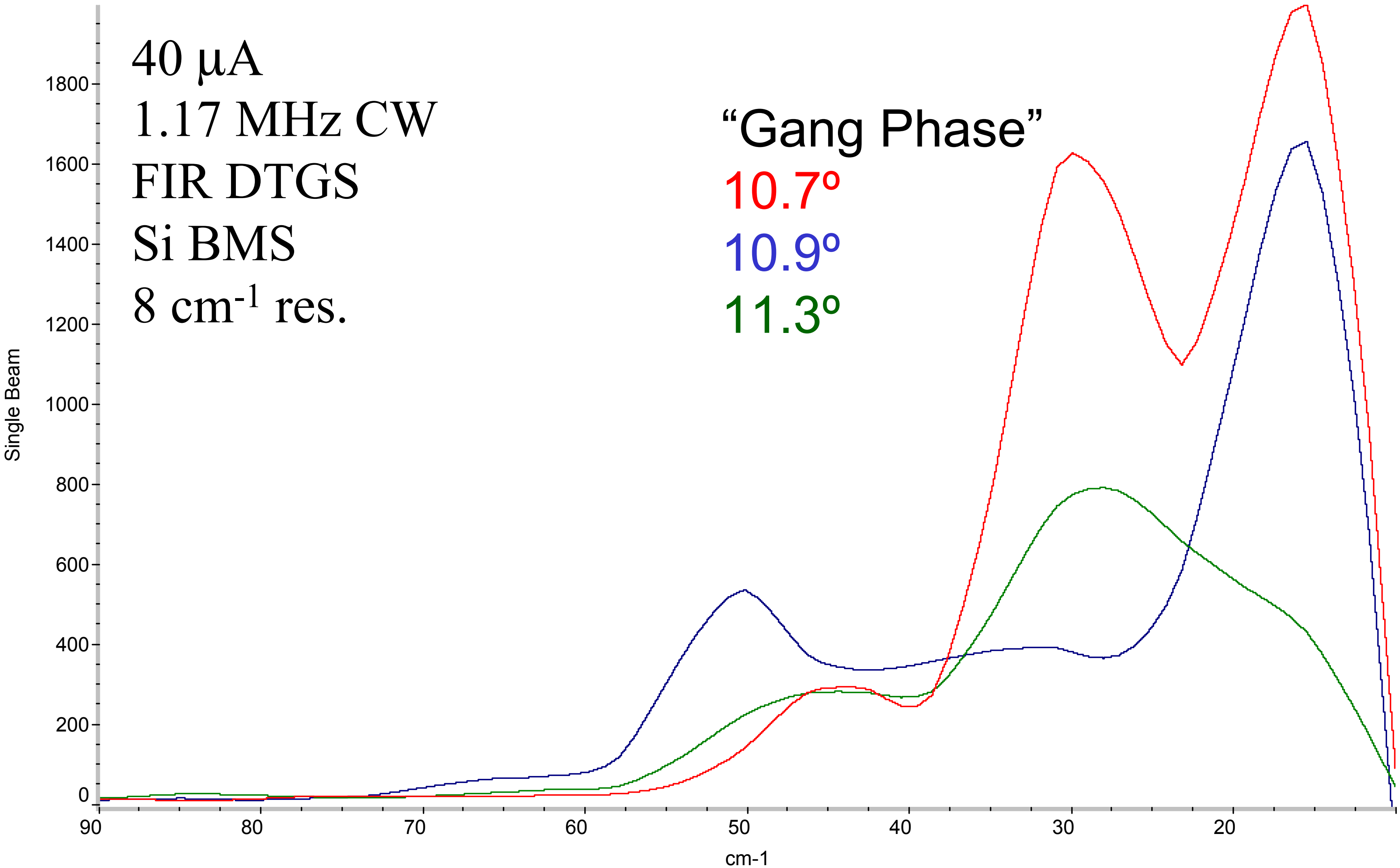
Noise Measurements of JLab THz Source



Spectral Changes with JLab RF Phase



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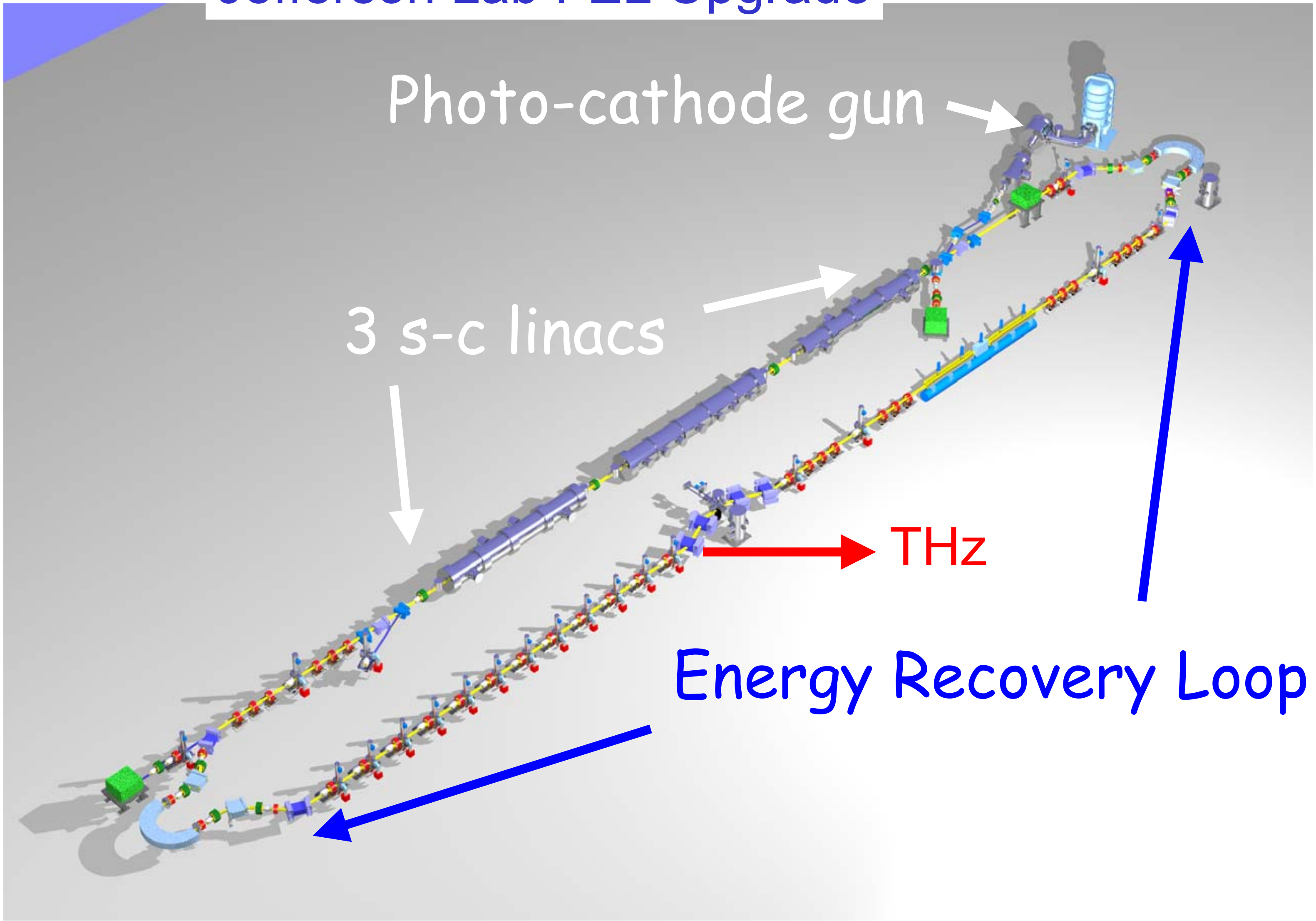
Jefferson Lab FEL Upgrade



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